The Preparation for Return Sample from Asteroid Ryugu by STXM at KEK-PF

*Hiroki Suga[1,2], Sakiko Kikuchi[3], Shuya Tan[1,4], Shohei Yamashita[2], Yasuo Takeichi[2], Daisuke Wakabayashi[2], Masao Kimura[2], Yoshio Takahashi[1,2], Yasuhito Sekine[4]

1. Graduate School of Science, The University of Tokyo., 2. Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK)., 3. Institute for Extra-cutting-edge Science and Technology Avant-garde Research (X-star), Japan Agency for Marine-Earth Science and Technology (JAMSTEC)., 4. Earth-Life Science Institute (ELSI), Tokyo Institute of Technology.

Hayabusa2 mission aimed at conducting sample return from a C-type asteroid named Ryugu, which is considered to be the parent body of the carbonaceous chondrite. As for the formation process of the Ryugu, the following hypotheses have been considered (i) internal heating case by short-lived radionuclide, (ii) impact heating case, (iii) incipient aqueous alteration case, and (iv) masking case by darker organic matter contributing to the low reflectance of Ryugu. If we can extract the information about the past collision and the water environment from the organic matter and secondary minerals in the actual Ryugu return sample, the scenarios above can be determined. In 2019, we analyzed the organic and inorganic simulated samples using a new Scanning Transmission X-ray Microscope (STXM) installed at BL-19A of Photon Factory.

As for the analog of the extraterrestrial organic matter, recovered samples of organic simulants of planetary bodies (OSPBs) from impact experiment described in [Sekine et al., 2018, MAPS] was used. STXM measurement was performed for the shock experienced OSPBs which recovered from shock wave with 0, 2, 5, 10, and 12 GPa. On the other hand, synthesized secondary saponite which was described in [Kikuchi and Shibuya, 2019, Asteroid Science 2019, #2049] was used. After the 100 days synthesized experiment, the newly formed fibrous minerals were notably observed at the surface of the original olivine, these minerals were identified as a saponite by the lattice fringes using TEM. Both of these samples were dropped on the Formvar-membrane supported Cu-mesh grid before the STXM measurement. The exposure time of clay sample to the atmosphere was less than 3 min before it was mounted on the STXM to prevent oxidation of Fe(II) in saponite. STXM stack measurement was conducted to C K-edge of OSPBs and Fe L_{III}-edge of synthesized saponite. Several grains were measured to guarantee the reproducibility. In addition, repeated stack measurement (9 times) was conducted to confirm the X-ray irradiation damage.

The C-XANES feature of shock-recovered OSPBs above about 7 GPa and 400 ˚C, which would be achieved in a typical asteroid belt collision, showed that the aromatic and graphite peaks are dominant with broad shape. From these results, we can summarize that (i) the aromatic and graphite peaks were not remarkable in the unheated sample, (ii) the aromatic and graphite peaks were confirmed but broad in the collision experienced sample, and (iii) the aromatic and graphite peaks become sharp and remarkable in the long-term heating sample. It is indicated that to distinguish between short-term heat event by collision and long-term heating event by radioactive elements is possible by C-XANES features.

Even if saponite is a common product of the low-temperature water-rock reaction between water and mafic minerals on Earth, Fe(II)-saponite is easily oxidized to Fe(III)-saponite under the atmospheric condition. In this study, the Fe(II) in the saponite is obviously detected by the minimized oxidation. Besides, we checked the beam damage on the Fe(II)-saponite oxidation by repeating measurements in the same field of view, the peak intensity of Fe(III) did not increase clearly shown. These results suggested that

STXM is better enough to identify the Fe(II)-saponite, and the best measurement condition of the extraterrestrial secondary minerals is an air-isolated system throughout the sample preparation to the analysis.

Throughout this study, the C-XANES analysis results of OSPBs gave us the evaluation criteria to determine the Ryugu formation scenarios. The synthesized redox-sensitive clay minerals analysis by STXM-XANES also contribute to the detailed identification of clay mineral species and its related water redox condition, which is also useful to determine scenarios of Ryugu alteration.

Keywords: Hayabusa2, Ryugu, STXM, Organic Matter, Saponite, Synchrotron Radiation

